

VIKING LABORATORIES INC.

705A

PICOAMMETER

1-0-20

OPERATING AND SERVICE MANUAL



EG&G

LABORATORY PRODUCTS DIVISION

MP MASTER



MA28993

ME 910A

All EG&G Laboratory Products Division instruments are warranted to be free from defects in material and workmanship for a period of one year.

Service is available from our plant in Goleta, California, and from certain field offices. When returning an instrument to the factory, please contact the Picoammeter Sales Department for authorization to return the unit and then consult the packaging instructions contained in this manual prior to shipping the instrument.

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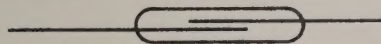
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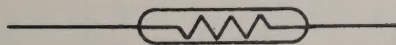
SYMBOLS AND ABBREVIATIONS

ADC	Analog-to-Digital Converter	milli (m)	10^{-3}
AUTO	Automatic	millisecond (ms)	10^{-3} second
a. c.	Alternating current	millivolt (mv)	10^{-3} volt
amp (a)	Ampere	milliamp (ma)	10^{-3} ampere
BCD	Binary Coded Decimal	micro (μ)	10^{-6}
BUG	Dual In-line Integrated Circuit	microsecond (μ s)	10^{-6} second
CCW	Counterclockwise	microvolt (μ v)	10^{-6} volt
CW	Clockwise	microamp (μ a)	10^{-6} ampere
CMR	Common Mode Rejection	nano (n)	10^{-9}
DAC	Digital-to-Analog Converter	nanosecond (ns)	10^{-9} second
DCU	Decimal Counting Unit	nanoamp (na)	10^{-9} ampere
DEC	Decrease	NBCD	Natural Binary Coded Decimal (1248)
DTL	Diode-Transistor Logic	NMR	Normal Mode Rejection
db	Decibel	O. R.	Over Range
femto (f)	10^{-15}	O. S.	One Shot
femtoamp (fa)	10^{-15} ampere	opamp	operational amplifier
F/F	Flip-Flop	pico (p)	10^{-12}
F-R DCU	Forward-Reverse Decimal Counting Unit	picoamp (pa)	10^{-12} amperes
f. s.	Full Scale	pot	potentiometer
Giga (G)	10^9	P. C.	Printed Circuit
Gigaohm (G Ω)	10^9 ohms	REM	Remote
Hz	Cycles per second	RMS	Root-Mean-Square
IGFET	Insulated Gate Field Effect Transistor	sec (s)	second
INC	Increase	Tera (T)	10^{12}
Kilo (K)	10^3	Teraohm (T Ω)	10^{12} ohm
KHz	10^3 cycles per second	v	volt
K Ω	10^3 ohms	w	watt
LSD	Least Significant Digit	$^{\circ}$ C	Degrees Celsius
MAN	Manual	$\cong$	approximately
MHz	10^6 cycles per second	Σ_j	Summing junction
MSI	Medium Scale Integration	Ω	Ohm
MSD	Most Significant Digit	% f. s.	percent of full scale
Mega (M)	10^6	% r.	percent of reading
M Ω	10^6 ohms		

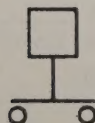
BLOCK DIAGRAM SYMBOLS



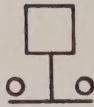
reed relay



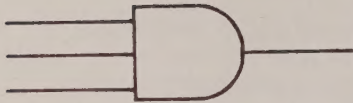
Hi-meg resistor ($>10^7 \Omega$)



Push button switch (N.O.)



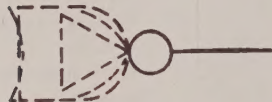
Push button switch (N.C.)



AND Gate



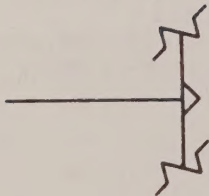
OR Gate



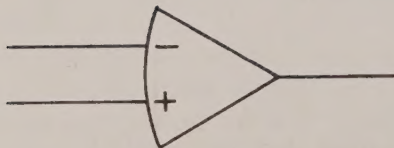
inversion



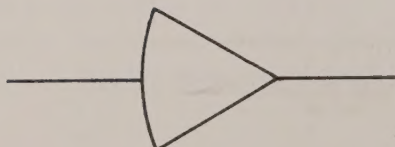
screw driver adjustment



a.c. coupled input (capacitor)



Differential Operational Amplifier



single-ended inverting operational amplifier

Section 1. General Information and Specifications

1.1 GENERAL DESCRIPTION

The EG&G Model 705A Picoammeter is an all solid state instrument with the capability of measuring positive or negative direct current from $\pm 10\text{ma}$ to $\pm 3 \times 10^{-13}$ amperes full scale in twenty-two 1-3-10 range steps. Range changing and polarity selection are controlled manually from the front panel. An output is provided for analog recording of current value (-1v to $+1\text{v}$ full scale, polarity opposite to input current).

1.2 METER SCALING

Current applied to the input BNC connector is displayed on a 3-3/4" 1% dual scale meter movement. The two scales provide display sequence of 1-3-10 (see Figure 1).

1.3 SPECIFICATIONS

1.3.1 Ranges

Full scale ranges are in twenty-two (22) steps from 10^{-2} amperes to 3×10^{-13} amperes full scale with an eleven decade RANGE switch and a X3 METER multiplier.

1.3.2 Polarity Definition

Positive polarity is conventional current *into* the center conductor of the BNC INPUT connector.

1.3.3 Accuracy (measured at analog output)

Accuracy is specified as the worst-case errors accumulated when calibrated according to the procedure outlined in this instruction manual. The accuracy specification is valid at $20^{\circ}\text{C} \pm 1^{\circ}\text{C}$, 50% relative humidity for one month after calibration.

Accuracy does not include effects of input voltage offset or current offset. The temperature coefficient for each range is given in Section 1.3.3.1.

1.3.3.1 Temperature Coefficient

This specification is applicable only to the accuracies stated in Table 1.

Table 1. ACCURACY

Range	Accuracy %F.S.
10^{-2} through 10^{-5}	.2
10^{-6}	.4
10^{-7}	.6
10^{-8}	.8
10^{-9}	1.25
10^{-10}	1.5
10^{-11}	1.75
10^{-12}	2.0

NOTE: Fixed Ranges—Ranges adjustable to stated accuracy under stated conditions with EG&G Model 601A Pico-Calibrator.

1.3.4 Controls

RANGE 10^{-2}a through 10^{-12}a in eleven decades

METER 1.0, 0.3, and OFF

POLARITY Positive and negative

NOTE: The METER and polarity (MODE) controls do not effect a change in scaling or polarity of the analog output.

1.3.5 Input Resistance

The maximum input resistance and corresponding voltage drop for full scale currents are shown in Table 3.

Table 2. TEMPERATURE COEFFICIENT

Range	Temperature Coefficient (PPM/ $^{\circ}\text{C}$)
10^{-2} through 10^{-5}	± 100
10^{-6} through 10^{-8}	± 300
10^{-9} through 10^{-12}	± 2000

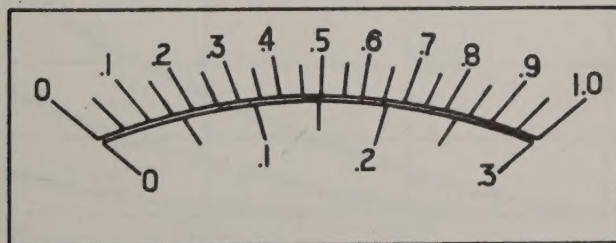


FIGURE 1. METER SCALE.

Table 3. INPUT RESISTANCE

Range	Input Resistance (Ohms)	Voltage Drop for Full Scale Input
10 ⁻¹²	100 M	100 μ V
10 ⁻¹¹	10 M	"
10 ⁻¹⁰	1 M	"
10 ⁻⁹	100 K	"
10 ⁻⁸	10 K	"
10 ⁻⁷	1 K	"
10 ⁻⁶	100	"
10 ⁻⁵	10	"
10 ⁻⁴	1	"
10 ⁻³	.1	"
10 ⁻²	.1	1mv

1.3.6 Input Voltage Offset

Temperature Coefficient	Less than 150 μ V/ $^{\circ}$ C from 5 $^{\circ}$ C to 50 $^{\circ}$ C
Drift	3mv maximum in 1 week after 1 hour warmup
Adjustment	Coarse and fine on rear panel

NOTE: 1mv of offset results in 0.1% of instrument offset on 10⁻² through 10⁻¹² ranges.

1.3.7 Input Current Offset

Temperature Coefficient (with voltage offset adjusted to zero)	Less than 10 ⁻¹⁵ amps/ $^{\circ}$ C from 5 $^{\circ}$ C to 50 $^{\circ}$ C
Steady State	10 ⁻¹⁴ a maximum

1.3.8 Risetime

For a step function of input current, risetime is defined as the 10%-90% response time at the analog output. This specification is valid up to 100pf of shunt input capacitive loading. For loading in excess of 100pf refer to Section 1.3.8.1.

1.3.8.1 Input Capacitance Loading Effects

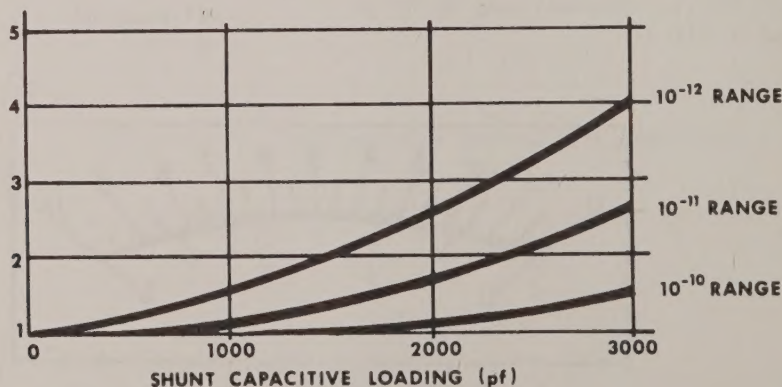
Shunt input capacitance should be kept to a minimum in order that the maximum bandwidth and signal-to-noise ratio be maintained. Shunt capacitance loading will generally result in a decrease in bandwidth* and an increase in noise.

Graph 1 illustrates the effect of capacitance loading on risetime (bandwidth). To use the curve, multiply the risetimes in Table 4 by the "Risetime Factor" determined for the particular range in question and the approximate value of shunt capacitance loading.

The effect of shunt capacitance on noise is given in Section 1.3.9.

Table 4. RISETIME
(min. damping, fully CCW)

Range	Risetime (10%-90%)
10 ⁻¹²	200 ms
10 ⁻¹¹	40 ms
10 ⁻¹⁰	5 ms
10 ⁻⁹	1 ms
10 ⁻⁸	250 μ s
10 ⁻⁷ through 10 ⁻²	150 μ s



GRAPH 1. RISETIME FACTOR.

*In some cases shunt loading will cause overshoot in the step function response, requiring adjustment of the DAMPING control for a critically damped response.

1.3.9 Noise

The total peak to peak noise from .1Hz to 50KHz at the analog output will be less than the limits specified in Table 5 with a probability of .9.

Table 5. NOISE (minimum damping)

Range	Peak to Peak Noise (mv) at Capacitive Loading	
	0pf	1000pf
10 ⁻¹²	75	750
10 ⁻¹¹	50	500
10 ⁻¹⁰	40	400
10 ⁻⁹	20	200
10 ⁻⁸	10	100
10 ⁻⁷	2	20
10 ⁻⁶	<.5	.5
10 ⁻⁵	<.5	.5
10 ⁻⁴ through 10 ⁻²	<.5	.5

1.3.10 Damping

A rear panel DAMPING control allows control of bandwidth/risetime to reduce effects of system and cable noise on 10⁻⁸ through 10⁻¹² ranges. Table 6 shows the effect on noise and bandwidth for the maximum damping setting.

Table 6. DAMPING CONTROL CHARACTERISTIC
(Maximum setting, fully CW)

Range	Noise Reduction Factor	Risetime Increase Factor
10 ⁻¹²	≈ 10	≈ 15
10 ⁻¹¹	≈ 10	≈ 15
10 ⁻¹⁰	≈ 10	≈ 40
10 ⁻⁹	≈ 10	≈ 40
10 ⁻⁸	≈ 10	≈ 50

1.3.11 Output

Scaling ±1v F.S. polarity opposite to input
Source Resistance 510 ohms, nominal

1.3.12. Output Connections

Table 7. J-3 ACCESSORY Connections

Pin	Function
1 - 5	
7	Blank
9 - 21	
6	Bipolar Analog 1v F.S.
8	Analog Common
22	+15v d.c.
23	-15v d.c.
24	Common

1.3.13 Noise Rejection

Common Mode Noise — The input connector to the 705A is isolated from the chassis with approximately 300pf in parallel with 500 megohms. A maximum difference in potential of ±150v can be sustained between the input connector and chassis. At 115v RMS, 60Hz, there will be no degradation in any specification.

Normal Mode Noise — See Sections 1.3.8, 1.3.9, and 1.3.10.

1.3.14 Environment

Temperature 5°C - 50°C
Humidity 0 - 50% relative humidity

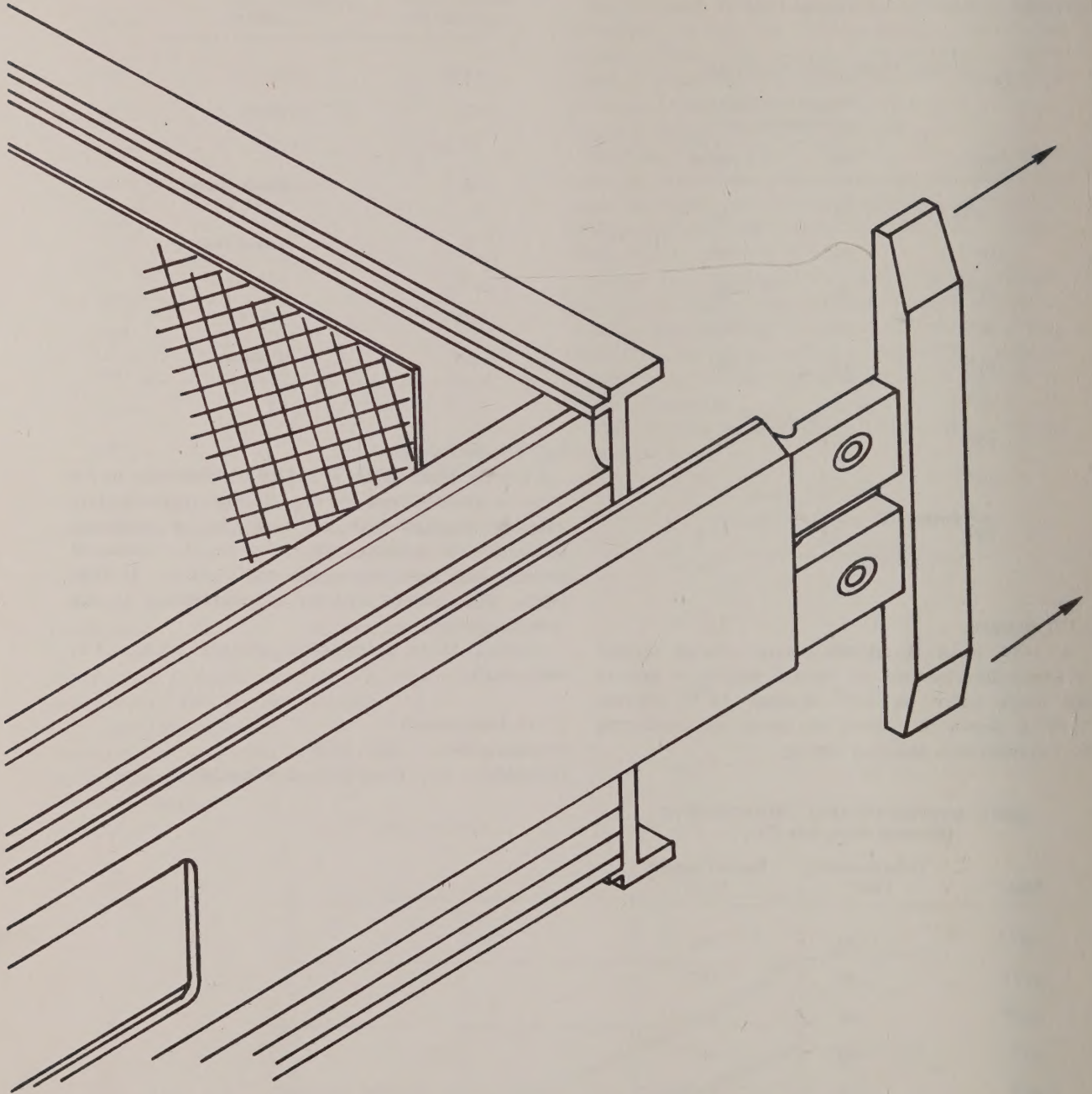


FIGURE 2. REAR END CAPS.

Section 2. Installation

2.1 INCOMING INSPECTION

This instrument was inspected both mechanically and electrically before shipment. The instrument should be in operating condition upon receipt. However, the top cover should be removed and the instrument inspected for damage prior to applying power. If there is damage or a deficiency, see the WARRANTY on the inside of the front cover. There should also be packaged with the instrument the following items: Instruction Manual and the mating connector for the ACCESSORY output (Amphenol 57-30240).

2.2 MECHANICAL INSTALLATION

The instrument can be operated as a bench top unit or rack mounted. Rack mounting ears are available from EG&G Laboratory Products Division, Goleta, California.

Access for mounting the rack ears or chassis tracks is accomplished by snapping off the rear end caps (see Figure 2) and sliding the handle cover plate off. The rack mount ears are mounted to replace the front end caps.

IMPORTANT: Effects of mechanical vibration and input cable movement will generate noise currents, possibly causing undesirable meter fluctuations on the more sensitive ranges. Care should be taken to minimize flexing of input cable and all types of vibration in general.

The use of low noise cable, such as Amphenol No. 21-537, will reduce the effects of cable flexing.

2.3 ELECTRICAL CONNECTORS

Power 105-125v, 60Hz nominal, three-wire service.

Input Connector BNC type coaxial connector. Recommended hook up cable is Amphenol No. 21-537 with teflon insulated connectors to fully utilize the complete range of sensitivity.

NOTE: All connections, test fixtures, photomultipliers, systems, etc. *must* be shielded to eliminate or reduce the effects of power line radiation and/or physical movement of people or equipment (see Figure 3).

The chassis of the 705A is floating with respect to the BNC input connector. The voltage between chassis and the BNC connector shield must be maintained at less than 150v d.c. or 115v RMS 60Hz for proper operation.

2.4 OUTPUT CONNECTIONS

An analog output is provided for external meter display, recording, or DVM display. Scaling is $\pm 1.0v$ F.S. polarity opposite to input current polarity. The METER and MODE controls have no effect on the analog output.

Connection may be made directly to the BANANA jacks on the rear panel or via the ACCESSORY connector (see Section 1.3.12).

2.5 REPACKAGE FOR SHIPPING

The following is a general rule for repackaging an instrument for shipment.

Place instrument in original container. If original container is not available, a suitable one can be purchased from EG&G, Laboratory Products Division, Goleta, California.

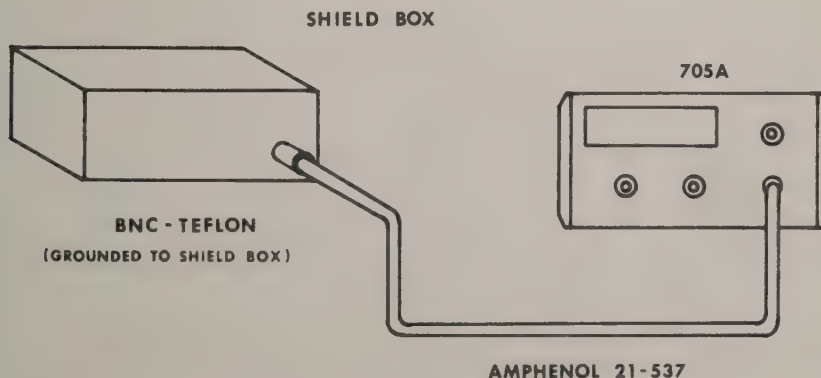


FIGURE 3. TEST FIXTURE SHIELDING.

If substitute container is used:

- a. Wrap instrument in heavy paper or plastic before placing in an *inner* container. .
- b. Use sufficient packing material around all sides of instrument and protect panel faces with cardboard strips.
- c. Place instrument and inner container in a heavy carton or wooden box and seal with strong tape or metal bands.
- d. Mark shipping container with "DELICATE INSTRUMENT — FRAGILE."

A tag should be attached to the instrument identifying the owner, P. O. number, and indicating the service or repair to be accomplished. Include the Model Number and the full Serial Number of the instrument.

SHIP TO:

EG&G
Laboratory Products Division
P.O.Box 755
Goleta, California 93017

Section 3. Operating Instructions

3.1 GENERAL

The Model 705A Picoammeter will measure d.c. currents from ± 10 milliamps to $\pm 3 \times 10^{-12}$ amperes full scale. A damping control may be used to reduce the effects of noisy input current. The analog output may be connected to an external meter, recorder, or DVM.

3.2 FRONT AND REAR PANEL DESCRIPTION

Following is a description of front and rear panel controls and indicators (Figure 4).

3.3 OPERATING INSTRUCTIONS

3.3.1 Normal Operation

- a. Connect the instrument to a grounded (three-wire) 105-125v, 60Hz outlet.
- b. Turn MODE to +.
- c. Turn METER to 1.0.
- d. Turn RANGE to 10^{-2} .
- e. Connect current to be measured to the INPUT by way of shielded coaxial cable (Amphenol 21-537) with teflon insulated connector(s).
- f. Turn the RANGE switch to successively higher sensitivities until a meter deflection is noted. If the deflection is upscale continue to Step g. If the deflection is downscale, turn the MODE switch to -.
- g. Continue turning the RANGE switch CW until the meter deflection is between 100% (1.0) and 10% (0.1) of full scale.
- h. If the meter deflection is less than .3 turn the METER switch to .3 for additional reso-

lution on the lower 1/3 of the range.

- i. The magnitude of current is read in amperes from the appropriate meter scale multiplied by the range setting. The polarity of the input current is read from the MODE switch.

Example:

RANGE 10^{-10}
METER .3 (read red .3 scale)
MODE +

Actual current is + (meter indication) $\times 10^{-10}$ amperes.

3.3.2 Damping Control

Noisy input current may cause a noticeable fluctuation of the meter movement on ranges below 10^{-8} . If this is the case, refer to Section II on mechanical installation and electrical connections.

If after checking for solid mechanical connections (no vibration) and PROPER SHIELDING the noise persists, the cause may be due to a noisy current source or excessive shunt input capacitance.

The reduction of this noise is possible by decreasing/increasing the bandwidth/risetime with a DAMPING control available at the rear panel. Fully CW is maximum damping, i.e., the further clockwise the control is turned, the more effective the noise reduction becomes. Proper adjustment is to turn the control fully CCW, and then advance it CW until the noise fluctuation becomes acceptable. NOTE: It cannot be emphasized enough that in most applications proper, vibration free, shielded connections will reduce the level of noise to entirely acceptable levels without resorting to the DAMPING control.

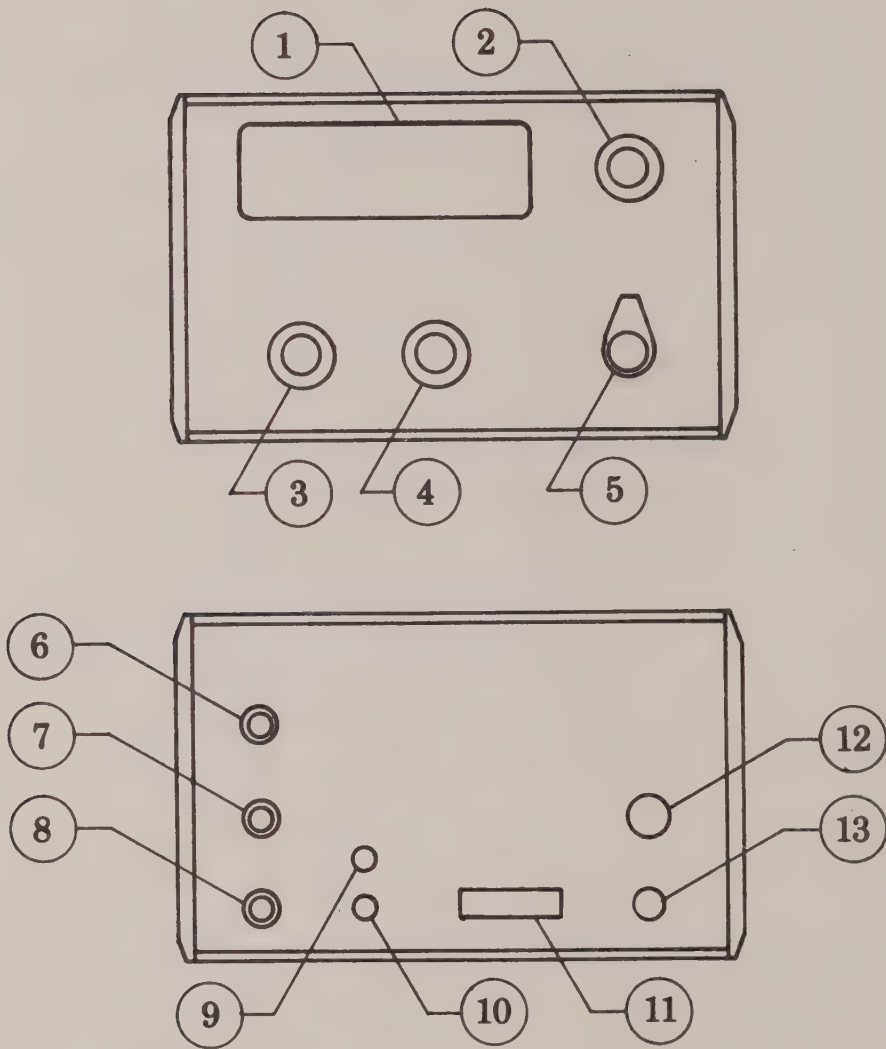


FIGURE 4. FRONT AND REAR VIEW.

1. METER DISPLAY Indicates magnitude of current applied to the INPUT in amperes.
2. RANGE Selects full scale sensitivity from 10^{-2} through 10^{-12} amperes.
3. MODE
 Positions: Power off
 + Positive current applied to INPUT causes upscale meter deflection.
 - Negative current applied to INPUT causes upscale meter deflection (polarity does not affect analog output).
4. METER
 Positions: Meter Off Disconnects Meter. Instrument functions normally.
 1.0 Full scale meter indication is 1.0 ampere.
 0.3 Full scale meter indication is 0.3 ampere (METER switch does not affect analog output).
5. INPUT BNC type input connector with shield cap.
6. COARSE ZERO }
7. FINE ZERO } Input offset adjustment
8. DAMPING Adjustable bandwidth/risetime control.
9. OUTPUT Analog output jacks.
10. ACCESSORY Analog output, provides power for EG&G Model 601A Pico-Calibrator.
11. FUSE 1 ampere 3AG
12. POWER CORD 105 - 125v, 60Hz nominal, three-wire service.

Section 4. Theory of Operation

The Model 705A is an operational type current measuring instrument. The low level operational amplifier is an all solid state design including a differential IGFET input stage with a semiconductor protected gate circuit.

4.1 CURRENT MEASUREMENT - SHUNT AND OPERATIONAL

The measurement of direct coupled current to sensitivities less than 1 picoampere has generally been accomplished by two methods: (1) Shunt, or electrometer method, or (2) Operational method.

4.1.1 Shunt Analysis

The Shunt Method is simply the application of a high input resistance voltmeter (electrometer) in measuring the voltage drop across a high value resistor (Figure 5).

Two limits may be applied to this expression:

1. $R_t \gg R_1$ (effect of shunt leakage with respect to the dropping resistor is negligible).
2. $R_s \gg R_1$ (circuit loading is negligible*).

The application of these limits simplifies the general expression and reveals the effects of leakage and loading.

When $R_t \gg R_1$, $R_s \gg R_1$

$$\Rightarrow V_m \cong V_s \frac{R_1}{R_s} \left[1 - \left(\frac{R_1}{R_t} + \frac{R_1}{R_s} \right) \right]$$

The term in brackets may be interpreted as an error term consisting of contributions by leakage

$\frac{R_1}{R_t}$ and loading $\frac{R_1}{R_s}$.

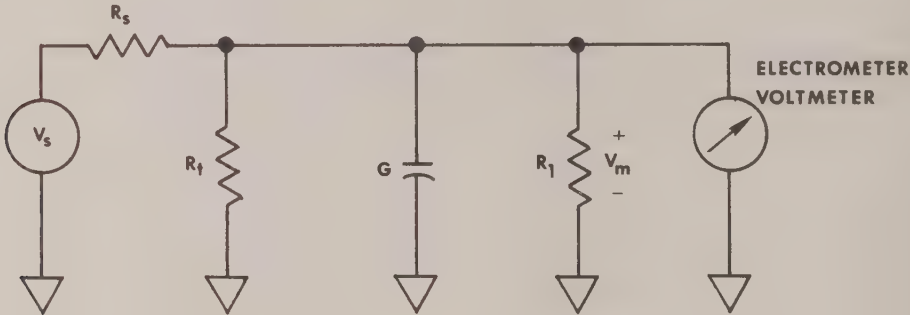


FIGURE 5. SHUNT MEASUREMENT MODEL.

Where:

V_s and R_s	Thevenin equivalent voltage and resistance
R_1	Shunt dropping resistor
R_t	Total leakage resistance—cable, electrometer, and connectors
V_m	Voltage drop measured by the electrometer
C_t	Total stray capacitance of cable, source, etc.

Solving for V_m :

$$V_m = V_s \frac{R_1}{R_s} \left[\frac{1}{1 + \frac{R_1}{R_t} + \frac{R_1}{R_s}} \right]$$

For example, suppose:

$V_s = 1$ volt
$R_s = 10^{12}$ ohms
$R_1 = 10^{10}$ ohms
$R_t = 5 \times 10^{13}$ ohms

$$V_m = .01 [1 - .01 - .002] \text{ volts}$$

The error contributed by leakage and loading is slightly in excess of 1%.

The effects of electrometer offset and the precision of R_1 become immediately evident—an offset

*The dual of an ideal voltmeter circuit where it is desirable to maintain $R_1 \gg R_s$.

of 1mv causing a 10% error and the inaccuracy of R_1 being directly related to an equal inaccuracy at the voltmeter input.

In addition, the large value of input resistance ($10^{10}\Omega$) has a serious effect on bandwidth. Only 100pf of C_t will effect a 2.35 second 10%-90% response to a step input.

4.1.2 Operational Analysis

The Operational Method is the application of a low leakage operational amplifier with resistive feedback to achieve the same end-measurement of low level direct coupled current.

for $A \gg 1$,

$$-V_o \approx V_s \frac{R_1}{R_s} \left[1 - \frac{1}{A} \left(\frac{R_1}{R_s} + \frac{R_1}{R_t} + 1 \right) \right]$$

Note that the error term is similar to that obtained for the shunt method, with the exception that *the effects are reduced by the open loop gain of the operational amplifier*. In fact, if the two inequalities are satisfied by a factor of 10, the

error term is simply: $1 - \frac{1}{A}$.

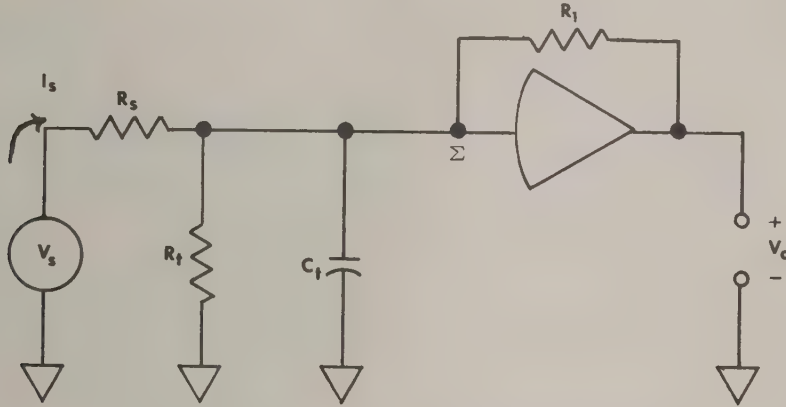


FIGURE 6. OPERATIONAL MEASUREMENT MODEL.

where:

V_s , R_s , R_t , C_t have the same definition as in the shunt analysis (Figure 5);

R_1 Voltage dropping resistor now inserted in the feedback of an operational amplifier;

$-A$ Open loop gain of the amplifier;

I_s Source current during measurement;

Σ Summing junction voltage;

V_o Amplifier output voltage.

The d.c. node equation at the summing junction:

$$\Sigma(G_s + G_t + G_1) - V_s G_s - V_o G_1 = 0$$

also, $V_o = -A\Sigma$.

Combining and rearranging:

$$-V_o = V_s \frac{R_1}{R_s} \left[\frac{1}{1 + \frac{R_1}{A} \left(\frac{1}{R_s} + \frac{1}{R_t} + \frac{1}{R_1} \right)} \right]$$

Let us apply the same circuit parameters as in the shunt example, where:

V_s 1 volt

R_s 10^{12}

R_1 10^{10}

R_t 5×10^{13}

A 20,000

Solving for V_o :

$$-V_o \approx .01 \left[1 - \left(\frac{.01 + .002 + 1}{20,000} \right) \right]$$

Thus, in the same application, the operational method has reduced the error from 1% to less than .01%.

Amplifier offset and the precision of R_1 contribute to error as in the shunt example.* However, the reductions of the errors are realized by:

1. Offset error is reduced by increasing the value of R_1 .** It will be seen later that this does not seriously affect the risetime as in the shunt example.
2. The inaccuracy of R_1 may be simply adjusted with a potentiometer in the feedback loop:

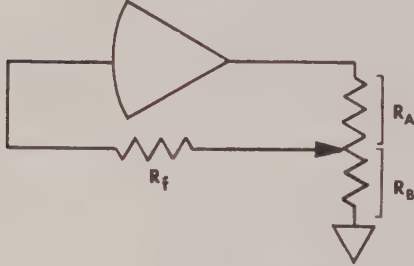


FIGURE 7. VARIABLE FEEDBACK.

where now the effective feedback resistor becomes:

$$R_1 \text{ (effective)} = R_f \left(\frac{R_a}{R_b} + 1 \right) + R_a$$

Thus, the variations in large value resistors may be easily adjusted by the ratio of $R_a : R_b$.

Referring to Figure 6, the input resistance may be determined by

$$R_{in} = \frac{\Sigma}{I_s} \text{ (assuming the leakage is negligible).}$$

Rearranging the node equation:

$$\Sigma = \frac{V_s G_s}{G_s + G_t + G_1 + AG_1}$$

Also,

$$I_s \cong V_s G_s, A \gg 1$$

$$\Rightarrow R_{in} \cong \frac{R_1}{A} \left[1 - \frac{1}{A} \left(\frac{R_1}{R_s} + \frac{R_1}{R_t} \right) \right]$$

*The summing junction offset voltage referred to the output is approximately: $(V_{offset}) \left(\frac{R_1}{R_s} + 1 \right)$

**This also increases the signal-to-noise ratio by the square root of the increase in R_1 .

For all practical purposes,

$$R_{in} \cong \frac{R_1}{A}$$

Again, a reduction by the open loop gain.

For a 2.35 second 10%-90% risetime as in the shunt case, the C_t would have to be increased by 20,000 to 2 μ f.

4.1.3 Summary

All circuit parameters being equal, the obvious improvements in performance realized by the operational method of current measurement are:

1. Lower input resistance
 - a. Reduction in source loading (lower source loading can be tolerated)
 - b. Faster response time
 - c. Less emphasis need be placed on extremely high leakage resistance at the input.
2. Low current measuring instruments may be easily calibrated for variations in large value resistors.

4.2 BLOCK DIAGRAM

The ME-705A is an operational type picoammeter, the circuitry being of all solid state design including a low leakage temperature and drift compensated IGFET operational amplifier.

Range changing is via a low level teflon insulated switch and appropriate feedback networks. Ranges 10^{-6} through 10^{-12} utilize variable feedback potentiometers allowing precise calibration to 1pa full scale.

A DAMPING control allows a variable amount of output signal to be applied to fixed feedback capacitors, thus slowing the time response when high noise level currents are measured.

4.3 THEORY OF BOOTSTRAP CALIBRATION

The basis of bootstrap calibration is dependent upon the accurate *Division of Current*, not the accurate *Generation of Current*.

One bootstrap step may be outlined:

1. Measure an unknown current with a precision wire wound resistor.
2. Divide that current by exactly 10 (or the factor of sensitivity increase to the next range).

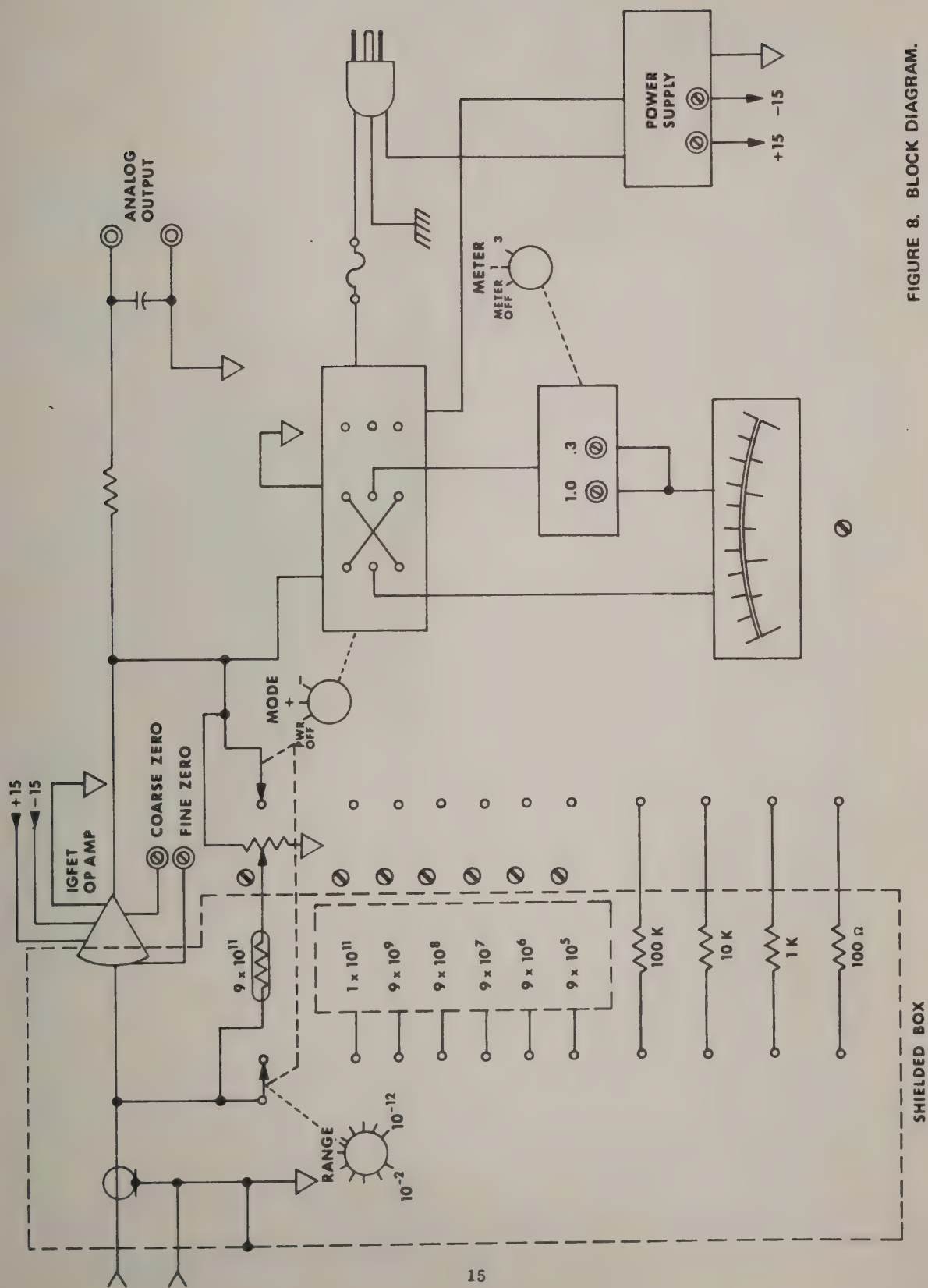


FIGURE 8. BLOCK DIAGRAM.

3. Use the divided current to adjust the next most sensitive range.

Successive bootstrap steps use the newly adjusted range to measure a new unknown current until all ranges are calibrated.

In essence, bootstrap calibration *eliminates* the weak link in the resistive calibration of picoam-meters.

BOOTSTRAP CALIBRATION DOES NOT DE-
PEND IN ANY WAY ON THE LONG TERM
STABILITY OF HI-MEG RESISTORS.

The bootstrap is subject to the following inaccuracies:

1. Precision of the current measurement (Step 1).
2. Voltage coefficient* of the current source when dividing (Step 2).
3. Accuracy of the adjustment (Step 3).
4. Input amplifier voltage and current offset af-fects all 3 steps.

The Model 705A accuracy specifications include these contributions to error in the worst cumulative case using the EG&G Model 601A as a source and Section V as a calibration procedure.

*Voltage coefficient of the EG&G Model 601A calibrator is kept to a minimum by use of 100PPM/volt resistors.

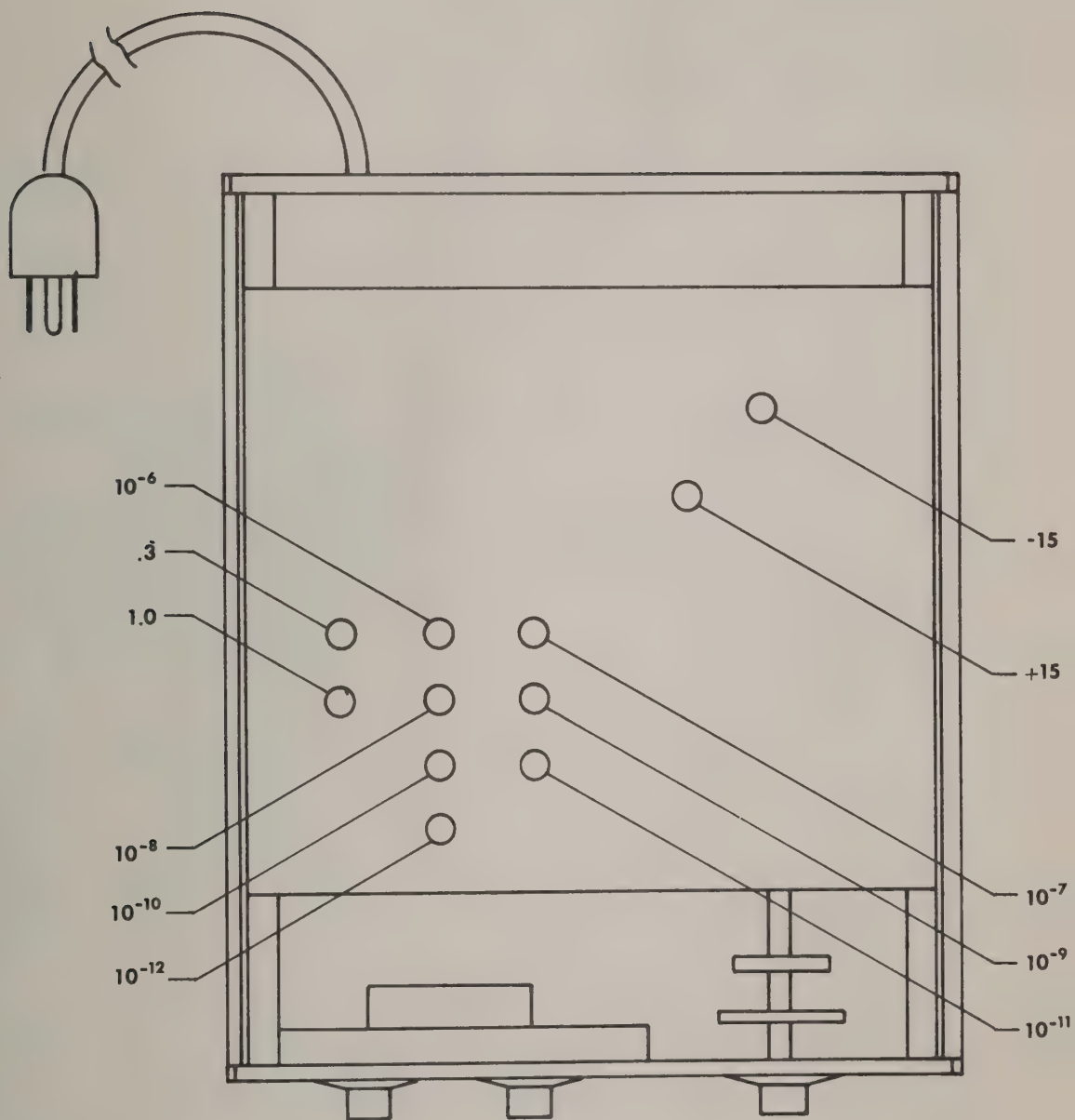


FIGURE 9.

Section 5. Calibration

5.1 TEST EQUIPMENT REQUIRED

- a. DVM $\pm 0.2\%$ — Accuracy at 1.0 volt (Dana 5400 or equivalent).
- b. EG&G TF-601A Pico-Calibrator.

5.2 PRELIMINARY CALIBRATION

Remove top cover; refer to Figure 9 for adjustments.

5.2.1 Meter Zero

With power turned off, adjust the mechanical meter zero to indicate precisely "0" on the meter scale.

5.2.2 Power Supply Adjustments

Power supply voltage access and adjustments are shown in Figure 9. Tolerance on ± 15 volt supplies are ± 100 mv.

5.3 METER CALIBRATION

1. Connect the DVM to the analog output (DVM range to 1-volt F.S.).
2. Plug the 601A power cable into the 705A ACCESSORY receptacle. (601A-01 is line powered.)
3. Connect the current output from the 601A to the 705A input cable (Amphenol 21-537 and teflon insulated BNC connectors).
4. Set 601A controls:
 - a. CURRENT +
 - b. RANGE 10^{-6}
 - c. VARIABLE Full CCW
 - d. MULTIPLIER 10
5. Plug 705A into a 105-125v 60Hz three-wire outlet.
6. Set 705A controls:
 - a. RANGE 10^{-5}
 - b. METER 1.0
 - c. MODE +
7. Adjust 601A VARIABLE for a DVM indication of 1.0 volt ± 1 mv.
8. Adjust 1.0 meter cal pot for 705A meter indication of 1.0.
9. 601A MULTIPLIER to 3.
10. 705A meter to .3
11. Adjust .3 meter cal pot for 705A meter indication of 0.3.

5.4 RANGE CALIBRATION

1. Set the 705A controls:
 - a. MODE PWR OFF
 - b. METER OFF
 - c. RANGE 10^{-6}
 - d. DAMPING Fully CW

2. Make connections as in Steps 1 through 3 in Section 5.3.
3. Set the 601A controls:
 - a. CURRENT +
 - b. RANGE 10^{-6}
 - c. VARIABLE Fully CCW
 - d. MULTIPLIER 1
4. Set DVM controls to 1.0 volt full scale.
5. Apply power to the 705A and turn the MODE switch to +. Allow 30 minutes for warmup.
6. Record DVM indication.
7. Turn 601A CURRENT to -.
8. Record DVM indication.
9. Difference between the absolute values of Steps 6 and 8 must be less than $200\mu\text{v}$. If not, perform Step 9a.
- 9a. Adjust rear panel zero controls so that the difference between the absolute values of Steps 6 and 8 is less than $200\mu\text{v}$.
- 10 $^{-6}$ Range Cal (Steps 10-14)
10. Turn 705A RANGE to 10^{-5} .
11. Turn 601A CURRENT to +, MULTIPLIER to 10.
12. Adjust 601A VARIABLE for DVM indication between .9v and 1.0v. Record DVM indication.
13. Turn 601A MULTIPLIER to 1.
14. Adjust 10^{-6} range adjustment pot to indicate value obtained in Step 13 ± 1 mv.
- 10 $^{-7}$ Range CAL (Steps 15-20)
15. 601A RANGE to 10^{-7} .
16. 601A MULTIPLIER to 10.
17. 601A VARIABLE to indicate .9 - 1.0. Record DVM.
18. 601A MULTIPLIER to 1.
19. 705A RANGE to 10^{-7} .
20. Adjust 10^{-7} range pot to value of Step 17 ± 1 mv.
- 10 $^{-8}$ to 10^{-10} CAL (Step 21)
21. Follow typical bootstrap steps for successive ranges until the 10^{-10} range has been calibrated.
- 10 $^{-11}$ CAL (Steps 22-27)
22. 601A RANGE to 10^{-11} .
23. 601A MULTIPLIER to 10.
24. 601A VARIABLE for DVM between .9v and 1.0v. Record DVM.
25. 601A MULTIPLIER to 1.
26. 705A RANGE to 10^{-11} .
27. Adjust 10^{-11} range pot to DVM value in Step 24 ± 1.5 mv.
- 10 $^{-12}$ CAL (Steps 28-34)
28. 601A RANGE to 10^{-12} .
29. 601A MULTIPLIER to 10.
30. 601A VARIABLE for DVM indication of 1.0v.
31. 601A MULTIPLIER to 1.

32. 705A RANGE to 10^{-12} .
33. 705A METER to 1.
34. Adjust 10^{-12} range pot to indicate 1.0 on 705A meter.

NOTE: Range calibration may be performed without use of DVM using only the meter indication to adjust zero and for bootstrap adjustments. This procedure will give rise to the following accuracy of calibration:

Range	Accuracy + %F.S.
10^{-12}	5.1
10^{-11}	4.4
10^{-10}	3.7
10^{-9}	3.0
10^{-8}	2.3
10^{-7}	1.6
10^{-6}	.9
10^{-5} through 10^{-2}	.2

Section 6. Replaceable Parts

This section contains information for ordering replacement parts. Following are parts lists in alpha-numeric order of their reference designations and the description and EG&G part number of each part, together with any applicable notes.

6.1 ORDERING INFORMATION

To obtain replacement parts, address order or

inquiry to EG&G Inc., Laboratory Products Division,
P.O. Box 755, Goleta, California 93017.

6.2 UNLISTED PARTS

To obtain parts not listed, include:

- a. Instrument Model Number
- b. Instrument Serial Number
- c. Description of the part
- d. Function and location of the part.

ME-705 SWITCH ASSEMBLY

QTY.	EG&G STOCK NUMBER	DESCRIPTION	REFERENCE DESIGNATION
1	150-0438	Capacitor 39pf Polystyrene	C1
1	150-0437	Capacitor 5pf Polystyrene	C2
1	150-0427	Capacitor 47pf Polystyrene	C3
1	150-0010	Capacitor 500pf Cer. Disc	C4
1	150-0027	Capacitor .005pf Cer. Disc	C5
1	150-0012	Capacitor .05pf Cer. Disc	C6
1	150-0020	Capacitor 47pf Cer. Disc	C7
1	150-0406	Capacitor 2pf Polystyrene	C8
1	150-0434	Capacitor 10pf Polystyrene	C9
2	480-5902	Transistor RN1020	Q1, 2
1	480-5306	Transistor 2N930 (Sel.)	Q4
1	470-1064	Resistor 4.7M 1/2w $\pm 5\%$	R2
1	470-1230	Resistor 900G $\pm 10\%$	R3
1	470-1231	Resistor 100G $\pm 10\%$	R4
1	470-1232	Resistor 9G $\pm 10\%$	R5
1	470-1236	Resistor 900M $\pm 10\%$	R6
1	470-1242	Resistor 90M $\pm 1\%$	R7
1	470-1243	Resistor 9M $\pm 1\%$	R8
1	470-2153	Resistor 909K $\pm 1\%$	R9
1	470-1444	Resistor 100K $\pm .1\%$	R10
1	470-1443	Resistor 10K $\pm .1\%$	R11
1	470-1442	Resistor 1K $\pm .1\%$	R12
1	470-1423	Resistor 100 μ $\pm .05\%$	R13
1	470-1055	Resistor 100K 1/4w $\pm 5\%$	R15
1		Resistor Factory Selected	R17
1		Resistor Factory Selected	R18
1		Resistor Factory Selected	R19
1		Resistor Factory Selected	R20

QTY.	EG&G STOCK NUMBER	DESCRIPTION	REFERENCE DESIGNATION
1	313-0051	Opamp, I.C.	AR1
2	150-0122	Capacitor 500 μ f/50v	C1, 4
2	150-0002	Capacitor 1 μ f (Mono)	C2, 5
2	150-0105	Capacitor 10 μ f/15v	C3, 6
1	150-0016	Capacitor 20pf	C7
1	150-0203	Capacitor .022 f	C8
4	480-1503	Diode SCE-2	CR1, 2, 6, 7
15	480-1101	Diode 1N4148	CR3, 4, 8 thru 19
1	480-1411	Diode 1N753	CR5
1	480-1102	Diode HD1812	CR20
4	480-5303	Transistor 2N3415	Q1, 3, 4, 6
2	480-5001	Transistor 2N396A	Q2, 5
2	480-6004	Transistor RCA No.40324	Q7, 8
2	480-5308	Transistor 2N3405	Q9, 11
1	480-5805	Transistor 2N3906	Q10
2	470-1002	Resistor 100 1/4w $\pm$ 5%	R1, 7
2	470-1036	Resistor 10K 1/4w $\pm$ 5%	R2, 8
2	470-1017	Resistor 1K 1/4w $\pm$ 5%	R3, 14
1	470-2115	Resistor 909 1/4w $\pm$ 1%	R4
2	470-5332	Pot. 200	R5, 11
2	470-2189	Resistor 750 1/2w $\pm$ 1%	R6, 9
1	470-2199	Resistor 866 1/2w $\pm$ 1%	R10
2	470-1024	Resistor 2K 1/4w $\pm$ 5%	R12, 13
2	470-0421	Resistor 8.2 1/2w $\pm$ 5%	R15, 16
2	470-0412	Resistor 120 1/2w $\pm$ 5%	R17, 39
7	470-5339	Pot. 5K	R18, 20, 22, 24, 26, 28, 30
7	470-1043	Resistor 20K 1/4w $\pm$ 5%	R19, 21, 23, 25, 27, 29, 31
1	470-1005	Resistor 240 1/4w $\pm$ 5%	R32
1	470-1016	Resistor 910 1/4w $\pm$ 5%	R33
2	470-5331	Pot. 100	R34, 35
1	470-1044	Resistor 24K 1/4w $\pm$ 5%	R36
1	470-1034	Resistor 6.8K 1/4w $\pm$ 5%	R37
1	470-1040	Resistor 15K 1/4w $\pm$ 5%	R38
1	470-0010	Resistor 470 1/4w $\pm$ 5%	R40
1	470-003I	Resistor 47 1/4w $\pm$ 5%	R41
1	560-0002	Transformer 115v a.c. 60Hz	T1

ME-705 P.C. BOARD

ME-705 CHASSIS ASSEMBLY

QTY.	EG&G STOCK NUMBER	DESCRIPTION
1	150-0012	Capacitor .05 20v C1
1	210-0505	Connector, μ -Ribbon J2
1	210-0512	Connector, BNC J1
1	210-0526	Banana Jack, Red (+)
1	210-0527	Banana Jack, Black (-)
1	210-2004	BNC Cap. Assembly
3	240-0510	SW Knob, Useco
2	250-0632	Panel, Side PC-4142
1	250-0635	Panel, Front, Fab. PC-4223
1	250-0662	Panel, Rear, Fab. PC-4224
1	250-0663	Panel, False Front
1	250-5004	Nomenclature Strip PC-4162
1	290-0010	ME-705 Meter (1MA)
1	470-2112	Resistor $511 \pm 1\%$ 1/4w R5
1	470-2218	Resistor $681 \pm 1\%$ 1/4w R6
3	470-5128	Potentiometer 25K R1, 2, 3
1	510-0408	Switch 1Pol-3 Pol w/Spr. S3
1	510-0409	Switch 2Pol-3 Pol w/AC SW S2
1	510-1054	Fuse 1 Amp S.B.
1	510-1601	Fuse Holder
1	600-1003	Power Cord (3 wire)
1	700-0105	ME-705 Board PD-3113
1	700-0229	Shielded Switch Assembly PD-1057
		Chassis, Half 5 1/4 PE-1067
1	250-0625	Cover, Bottom PC-4274
2	240-0004	Handle, Vinyl
1	240-0026	Bail, Instrument
4	250-0621	Cap, End PC-4127
1	250-0625	Cover Top PC-4147
2	250-0633	Trim, Side PC-4145
2	380-0628	Catch, Ball
8	280-0151	Screw, Ft. Hd. Socket *6-32NC x 1/2

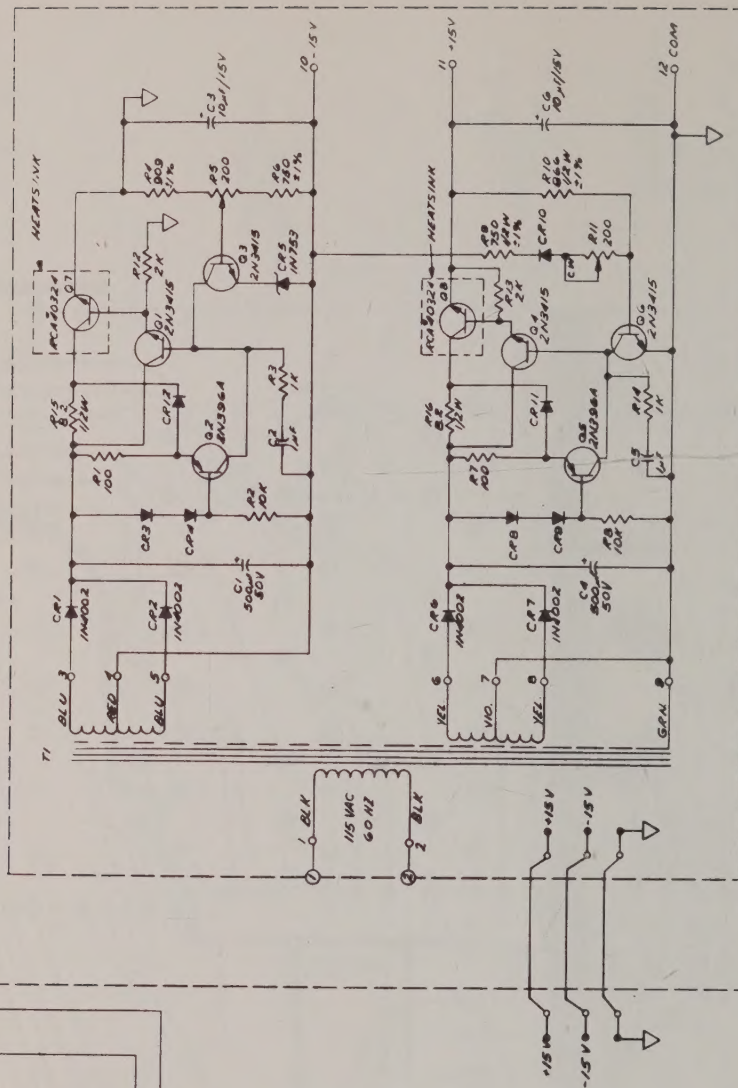
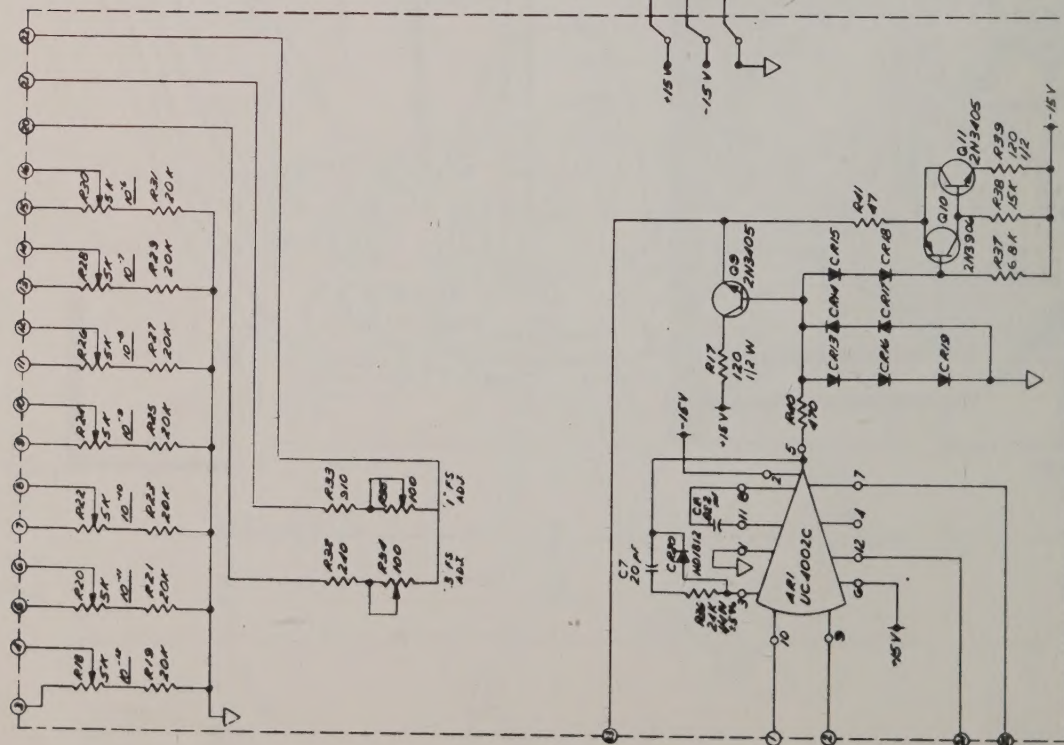


FIGURE 12. CIRCUIT BOARD SCHEMATIC 705A.



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